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## WATER HARDNESS IN BULGARIA – SPATIAL DISTRIBUTION AND POTENTIAL IMPACT ON HUMAN HEALTH

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**Abstract:** The article examines water hardness in Bulgaria by analyzing variations in calcium ( $\text{Ca}^{2+}$ ) and magnesium ( $\text{Mg}^{2+}$ ) levels across different regions of the country. Water hardness is measured in German degrees and is classified as very soft (0–4 °dH), soft (5–8 °dH), moderately hard (9–12 °dH), hard (13–18 °dH), and very hard (above 18 °dH). The undesirable effects of using hard water in everyday household activities and its potential impact on human health are also discussed. The aim of the publication is to identify regions in Bulgaria with varying water hardness levels and to assess the potential influence of calcium and magnesium on human health. **Materials and Methods:** A descriptive, comparative, and documentary methods were used. The analysis is based on published data from water supply companies, scientific publications on the topic, health documents, and reports. The geographical distribution is visualized through maps of regions in Bulgaria with different levels of water hardness. The results show significant regional differences depending on geological structure and water sources (groundwater, rivers, reservoirs, mountain springs, etc.). In Sofia, the water is soft with very low hardness (< 2.49 °dH). Along the Black Sea coast, water hardness varies in different parts of cities or regions, ranging from softer (8.4–9.4 °dH) to hard (17.4–19.1 °dH) and very hard (19.9–21.3 °dH). In Northwestern Bulgaria, drinking water hardness is moderate to hard (approximately 8–18 °dH). In Southwestern Bulgaria, the water is soft, although in some smaller settlements there may be local cases of higher hardness. In Plovdiv (11.1–13.8 °dH) and Asenovgrad (12.3–13.4 °dH), the water is hard, while in smaller settlements such as Sopot (3.1–3.4 °dH) and Karlovo (2.2–4.1 °dH), soft to moderately hard water is observed. Mountainous areas and parts of Southern Bulgaria also have soft water. From a health perspective, hard water is not considered harmful under normal consumption. Calcium and magnesium in water are beneficial to health; however, since the conducted studies do not include control groups to establish a direct relationship between human health and water hardness, the effects are classified as potential. Negative effects are observed in household settings—limescale buildup on appliances and reduced efficiency of cleaning and laundry detergents. **Conclusion:** Water hardness in Bulgaria is a factor with regional differences, affecting both everyday life and mineral intake, with the predominant effect on human health being positive. There is no convincing evidence that hard water causes kidney stone disease in healthy individuals. Numerous population-level scientific studies demonstrate that water hardness is not a factor in disease prevalence in specific regions.

**Keywords:** water hardness, health effects, spatial distribution

### 1. INTRODUCTION

Hard water is characterised by high concentrations of dissolved minerals, primarily calcium ( $\text{Ca}^{2+}$ ) and magnesium ( $\text{Mg}^{2+}$ ), as well as their sulfates and bicarbonates. Hardness is measured based on the quantity of these minerals in the water; the higher the concentration of calcium and magnesium, the harder the water becomes. Aluminum, iron, zinc, and manganese also contribute to hardness, though their presence is typically much lower and specific to certain regions. (1, 2)

Water hardness is typically measured in German degrees: very soft (0–4 °dH); soft (5–8 °dH); medium/moderately hard (9–12 °dH); hard (13–18 °dH) and very hard (over 18 °dH). Water hardness is measured in mg/l CaCO<sub>3</sub> or in German degrees (°dH).

According to the dissolved CaCO<sub>3</sub>, water hardness is classified as follows: soft – 0-60 mg/l CaCO<sub>3</sub>; medium/moderately hard – 61-120 mg/l CaCO<sub>3</sub>; hard – 121-180 mg/l CaCO<sub>3</sub> and very hard – over 180 mg/l CaCO<sub>3</sub>. (3)

A distinction is made between temporary hardness – caused by soluble calcium and magnesium bicarbonates (which can be reduced by boiling the water) – and permanent hardness – caused by sulfates, chlorides, and nitrates (which is not removed by boiling the water). (4)

Water hardness has a markedly negative effect on household life. This is due to two main reasons – the formation of limescale and resistance to detergents. With very hard and hard water, there is a stronger deposition of limescale in household appliances and on faucets; detergents foam with difficulty, white traces remain on glasses and dishes, and skin and hair feel dry after washing and bathing. With moderately hard water, frequent buildup of limescale is observed, the water feels "harder" during bathing, and a larger amount of soap, washing liquid, or laundry detergent is required. With soft water, less limescale is formed in boilers and household appliances, and there is less soap scum during washing. (5)

In Bulgaria, a large portion of groundwater is moderately hard to hard, but the exact values of Ca<sup>2+</sup> and Mg<sup>2+</sup> depend on the specific region. When soft rainwater falls onto the soil, it passes through the rocks in the Earth's crust (sedimentary and basalt layers) and reaches natural underground reservoirs and surface water bodies. When water passes through sedimentary rocks such as limestone, dolomite, and chalk, it absorbs soluble and insoluble forms of calcium and magnesium. Therefore, regions with a high content of these rocks, such as Dobrich, Silistra, Yambol, Haskovo, Pleven, and Montana, predominantly have hard water. Regions with a low content of sedimentary rocks, such as Sofia, Pernik, Kyustendil, Blagoevgrad, and Smolyan, have soft water. (6)

2. **THE OBJECTIVE** of the present study is to identify the regions and settlements in Bulgaria with varying water hardness and to evaluate the impact of calcium and magnesium on human health (benefits and negative effects).

### 3. MATERIALS AND METHODS

A descriptive, comparative, and documentary method was utilized. The analysis is based on published data from water supply companies, scientific publications on the subject, health documents, and reports. The geographical distribution is visualized through maps of the regions in Bulgaria.

### 4. RESULTS AND DISCUSSION

The hardness of tap water in Bulgaria is typically distributed by regions/cities, based on available data regarding water supply and the geology of the region. In different areas, hardness varies significantly depending on the water source (groundwater, rivers, reservoirs, mountain sources, etc.), as well as the geological composition of the rocks and the soil type. Locations with soft, moderately hard, and hard water are observed throughout the country. (7)

Distribution of water hardness by region according to generally accepted scales in Bulgaria:

- Southern Bulgaria

The water in Plovdiv is moderately hard to hard, with average values around 11.1–13.8 °dH across various water sources. Approximately 95% of the water in Plovdiv is extracted from underground sources via four pumping stations: South, North, East-1, and East-2. (8)

- Black Sea Coast

Varna utilizes water from three main sources: Kamchiya (via Kitka village), the Devnya springs, and Batova. Water supply zones in Varna receive mixed water: softer water (8.4–9.4 °dH) from Kamchiya for part of the region; hard water (17.4–19.1 °dH) from Batova, supplied to parts of the city center; and hard to very hard water (19.9–21.3 °dH) from the Devnya springs, which is the most widely used source in the city and the Varna province as a whole. <http://energywater.bg/mapa-tvrnosti-vody/> (9)

In Burgas, the water is generally moderately hard (approximately 8.4 °dH). The city receives its supply from two primary sources: the Kamchiya and Yasna Polyana reservoirs. (10)

- Northern and Northeastern Bulgaria

In Ruse and some surrounding areas, the water is hard (approximately 16 °dH). In Razgrad and Pleven, it varies around 15 °dH but frequently leans toward very hard.

- Northwestern Bulgaria

In Vidin, Montana, Vratsa, and the surrounding regions, the hardness of drinking water is typically moderate to hard (approximately 8–18 °dH), meaning the water is often categorized as "moderately hard" to "hard." (11)

- Southwestern Bulgaria

In Pernik, Kyustendil, and Blagoevgrad, the water is soft. In some smaller settlements in Southwestern Bulgaria, local instances of higher water hardness may occur (for example, in certain water supply points in the Kyustendil province or near Dupnitsa). (12)

- Sofia

In Sofia, the water is soft, with very low hardness ( $< 2.49$  °dH). Nearly 100% of the drinking water in Sofia is sourced from the Iskar and Beli Iskar reservoirs. These reservoirs are filled by mountain springs from the Rila Mountains, where sedimentary rocks constitute a small percentage, thus lacking the conditions for water "hardening." (13, 14) In the higher parts of the Rhodopes and the Balkan Mountains, the water is often softer to moderately hard, depending on the source. Water in the mountainous regions (Rila and Vitosha) is also softer because it originates from surface sources.

The softest water is found in Sofia and the mountainous regions. Harder water is found in the lowlands, particularly in the northern and northeastern regions, where underground water sources pass through limestone-rich rocks. In many provinces, hardness varies within different parts of the city or district—for instance, in Varna, Plovdiv, and Kyustendil, there are both softer and harder sources depending on the specific area.

*Fig. 1. Physical map of Bulgaria*



Source: <https://differentm.wordpress.com/weather/bgmaps/> (15)

Figures 1 and 2 present a physical and an administrative map of Bulgaria, based on data from the Water Supply and Sewerage (ViK) utility companies, illustrating the regions with varying levels of water hardness.

*Fig. 2. Administrative map of water hardness in Bulgaria*



Source: <https://cleanwater.bg/blog/tvardost-na-vodata> (11)

Table 1, based on an official report from the Water Supply and Sewerage (ViK) utility, presents the water hardness values for various settlements in the Plovdiv region (values are measured as total hardness in mmol/dm<sup>3</sup> and mg-equiv/dm<sup>3</sup>, where 1 mmol/dm<sup>3</sup> ≈ 5.6 °dH ≈ 3.5 mg-equiv/dm<sup>3</sup>). The data illustrate how water hardness varies across the specified towns and villages

**Table 1. Classification of water hardness in various settlements in the Plovdiv region (ViK data for various monitoring points)**

Place of residence	Total hardness (mmol/dm <sup>3</sup> )	Total hardness (°dH)	Classification
Plovdiv	2,34–2,56	13–14,5	Hard to very hard
Asenovgrad	2,20–2,40	12,3–13,4	Hard
Stamboliyski	2,20–2,54	12,3–14,2	Hard
Rakovski	2,46–3,00	13,7–16,8	Hard to very hard
Brezovo	2,85–3,00	16–16,8	Very hard
Parvomay	3,10–3,12	17,4–17,5	Very hard
Trud	1,48–1,60	8,3–9,0	Medium/moderately hard
Krichim	1,44–1,50	8,1–8,4	Medium/moderately hard
Perushtitsa	1,34–1,40	7,5–7,8	Medium/moderately hard
Sadovo	0,80–1,00	4,5–5,6	Soft to medium/moderately hard
Karlovo	0,40–0,74	2,2–4,1	Soft to medium/moderately hard
Sopot	0,56–0,60	3,1–3,4	Soft
Kaloyanovo	1,74–1,82	9,8–10,2	Medium/moderately hard
Banya	1,00–1,10	5,6–6,2	Soft to medium/moderately hard
Laki	1,02–2,44	5,7–13,7	Varies (soft to hard)
Hissarya	1,24–1,40	7,0–7,8	Medium/moderately hard

Source: <https://cleanwater.bg/blog/tvardost-na-vodata> (11)

According to water hardness standards and the settlements listed in the table, the data can be summarized as follows:

- In Plovdiv, Rakovski, Brezovo, and Parvomay, the water is hard to very hard.
- In Asenovgrad and Stamboliyski, the water is hard.
- In Trud, Krichim, Kaloyanovo, Perushtitsa, and Hisarya, the water is moderately hard.
- In Sadovo, Banya, and Karlovo, the water ranges from soft to moderately hard.
- In Laki and Sopot, the water varies from soft to moderately hard.

In larger settlements around Plovdiv, water hardness often exceeds 12 °dH. This is attributed to groundwater sources passing through limestone and carbonate layers. In smaller villages and higher terrains, the hardness is frequently lower (softer water).

#### **Impact of Hard Water on Human Health:**

##### 1. Physiological Benefits:

Calcium and magnesium in water are natural minerals that support bone and dental health and participate in neuromuscular functions. Some epidemiological studies indicate a correlation between higher magnesium intake via water and a lower risk of cardiovascular disease (as magnesium plays a vital role in heart rhythm and blood pressure regulation). (16, 17)

The relationship between water hardness and cancer risk has also been investigated. It is suggested that moderately high mineral content may have a protective effect against certain types of cancer; however, this effect is complex and varies according to mineral levels. Since available studies lack control groups to definitively prove a causal link, these effects are classified as potential. (18)

##### 2. Adverse Effects:

A correlation has been identified between water hardness and skin conditions such as dermatitis and eczema. Higher water hardness exerts a more negative, irritating effect on the skin due to its drying capacity. A similar effect is

observed on the hair. Potential negative effects in sensitive individuals, manifesting as gastrointestinal discomfort, are also a subject of discussion. (19)

### 3. Kidney Stones:

According to scientific data, there is no evidence that hard water causes kidney stones. Calcium in water does not increase the risk in healthy individuals. The risk depends largely on dietary habits, genetic predisposition, and overall fluid intake.

### 4. Impact on Infants and Young Children:

Scientific research indicates that hard water is safe for consumption by this age group. However, for the consumption and preparation of infant formula, water with low mineralization or specifically labeled "baby water" is recommended.

## 3. CONCLUSIONS

Water hardness is determined by the geological structure of the region and the specific water sources.

In Bulgaria, water hardness values are mixed, ranging from soft to hard.

The softest water is found in Sofia and the mountainous regions. Harder water is prevalent in the lowland areas of the country, particularly in the northern and northeastern regions.

In many provinces, water hardness varies across different parts of the city or the administrative district.

Hard water is not harmful to health under normal consumption levels. In many cases, it even contributes to the daily intake of essential minerals. Since existing studies often lack control groups to definitively prove a causal link between human health and water hardness, such associations remain classified as potential.

Water hardness in Bulgaria is a factor characterized by regional variations, influencing both daily life and mineral intake, with the predominant effect on human health being positive. At the population level, it has been demonstrated that water hardness is not a significant factor in disease morbidity across the studied regions.

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